US007786662B2

(12) **United States Patent**
DiCarlo

(10) **Patent No.: US 7,786,662 B2**
(45) **Date of Patent: Aug. 31, 2010**

(54) **DISPLAY USING A MOVABLE ELECTRON FIELD EMITTER AND METHOD OF MANUFACTURE THEREOF**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 841 days.

(21) Appl. No.: **11/134,163**

(22) Filed: **May 19, 2005**

(65) **Prior Publication Data**

US 2006/0261724 A1 Nov. 23, 2006

(51) **Int. Cl.**
H01J 1/30 (2006.01)

(52) **U.S. Cl.** **313/495**; 313/309; 313/351

(58) **Field of Classification Search** 313/309–311, 313/336, 351, 422, 495–497; 315/169.1, 315/169.3; 438/20; 257/10
See application file for complete search history.

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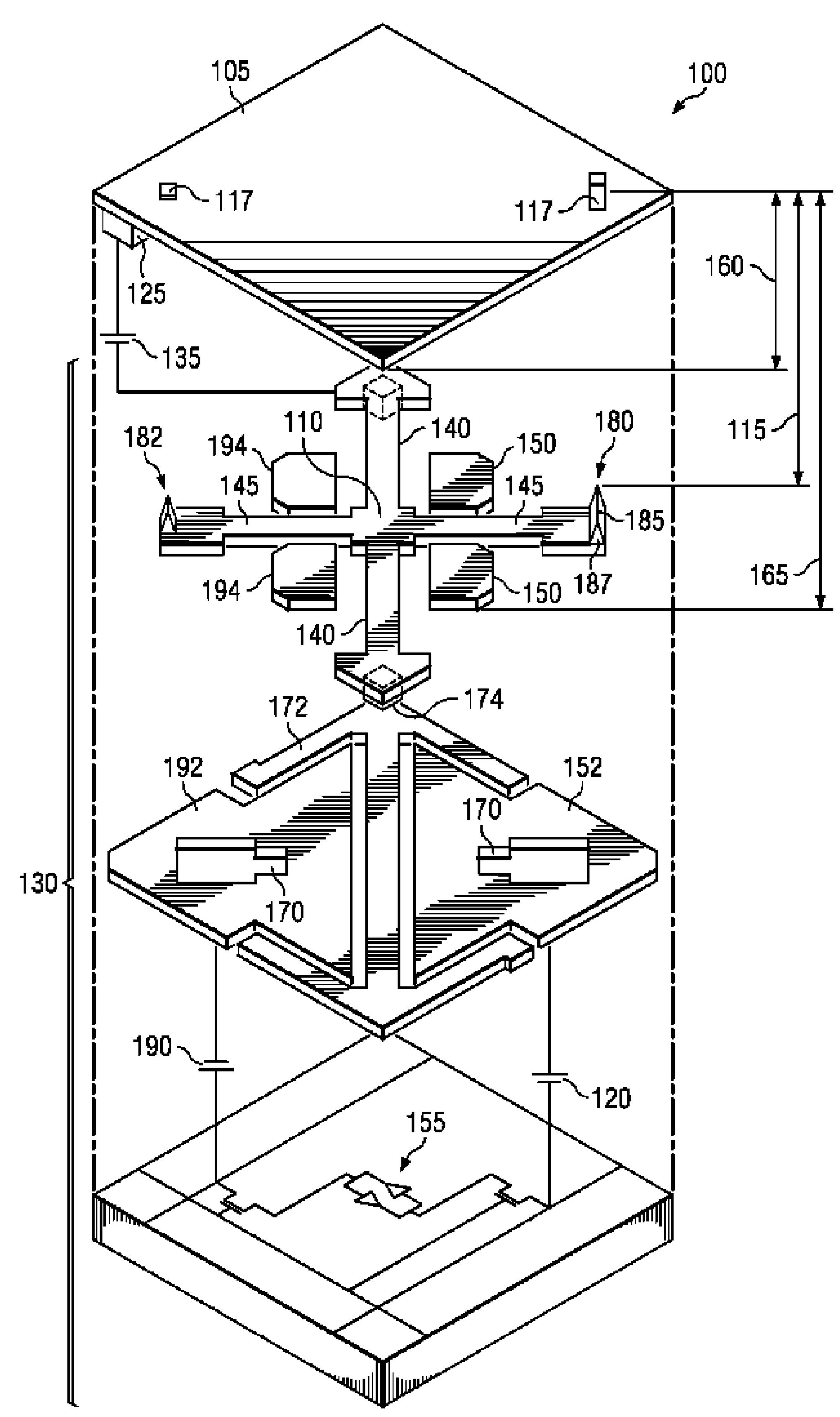
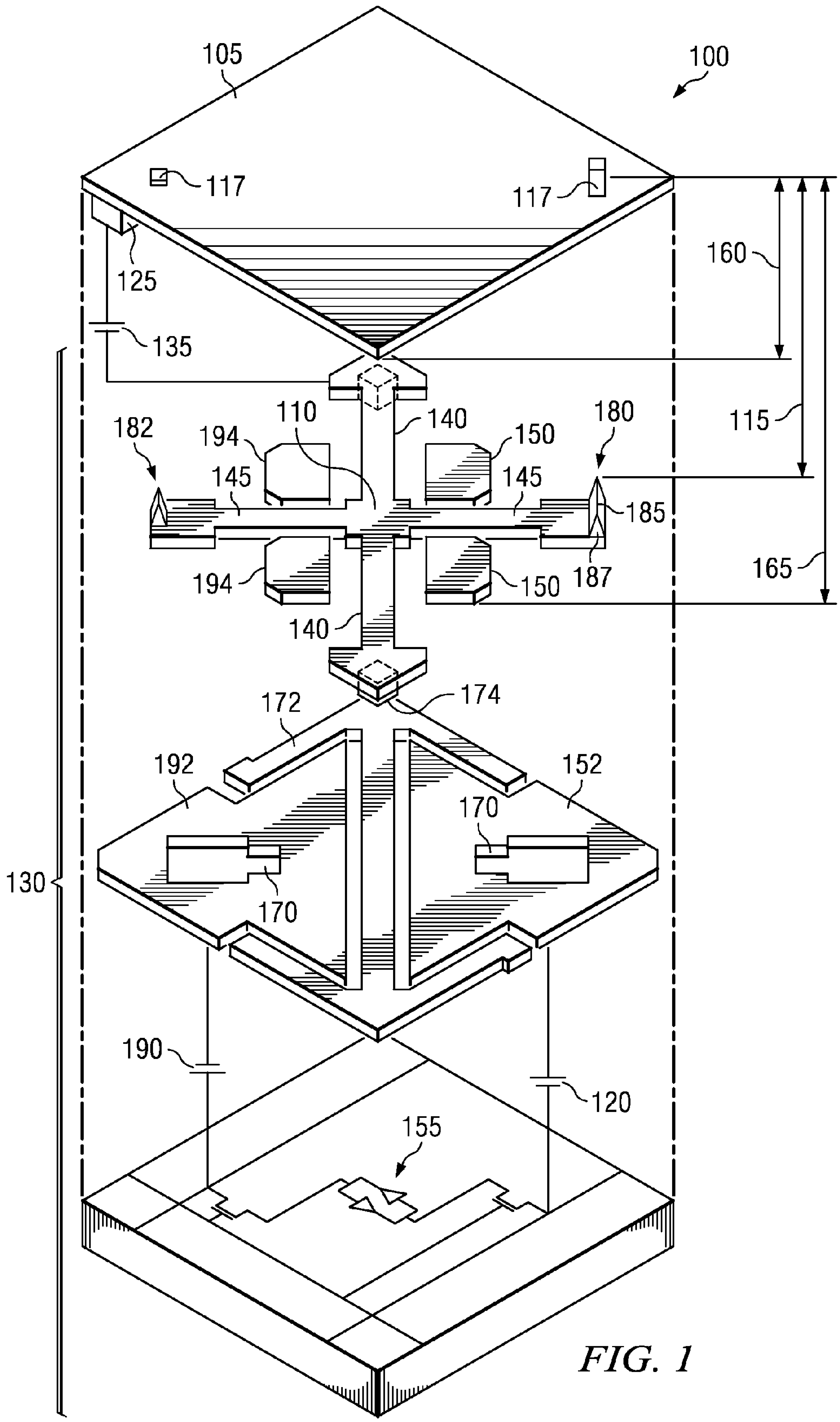
(57) **ABSTRACT**

A field emission device **100** comprises an anode **105** and a cathode **110** separated by a distance **115** from the anode. At least one of the anode or cathode is configured to move with respect to the other in response to an applied voltage **120** to at least one of the anode and cathode, the distance being adjustable by the movement.

19 Claims, 7 Drawing Sheets





105
100
117
117
125
160
135
115
110
140
150
194
182
180
145
145
185
187
194
150
165
140
174
172
192
152
170
170
130
190
120
155

FIG. 1

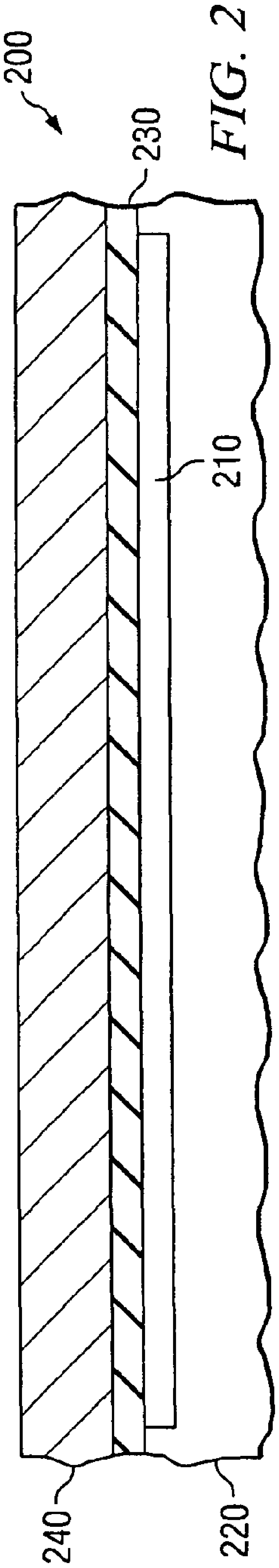


FIG. 2

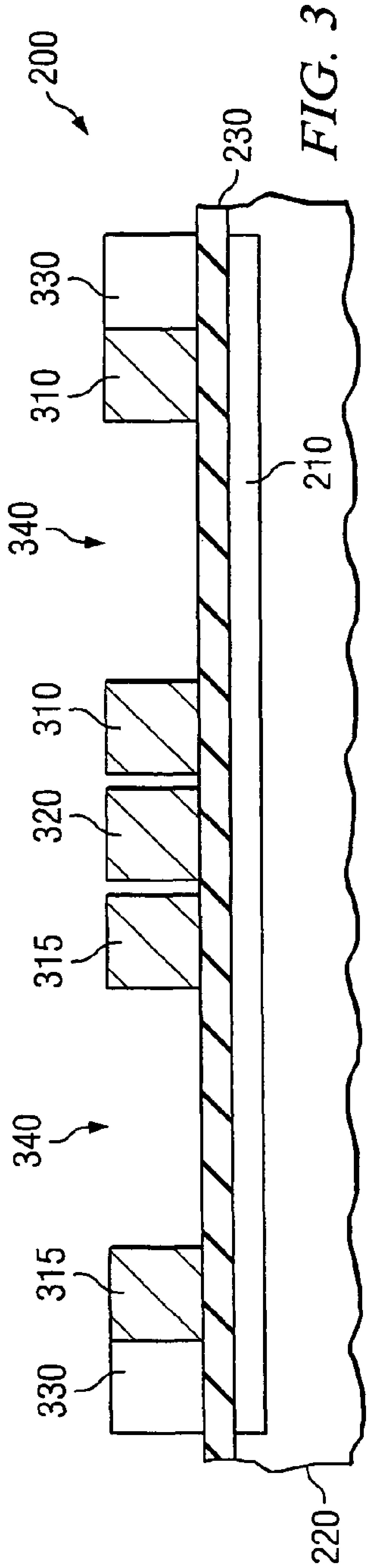


FIG. 3

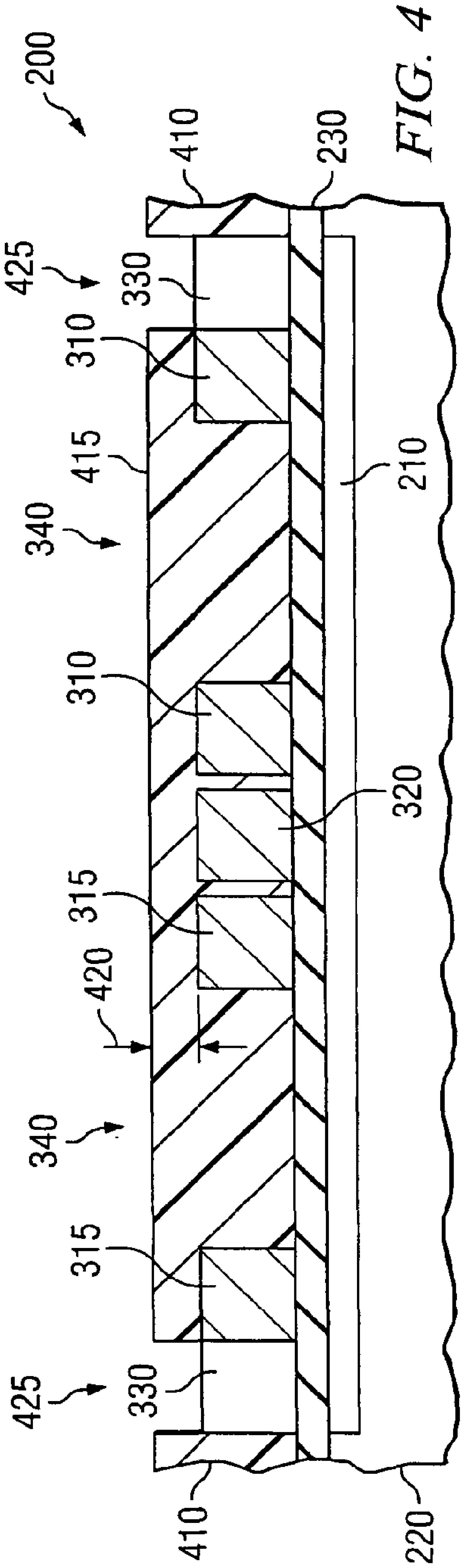


FIG. 4

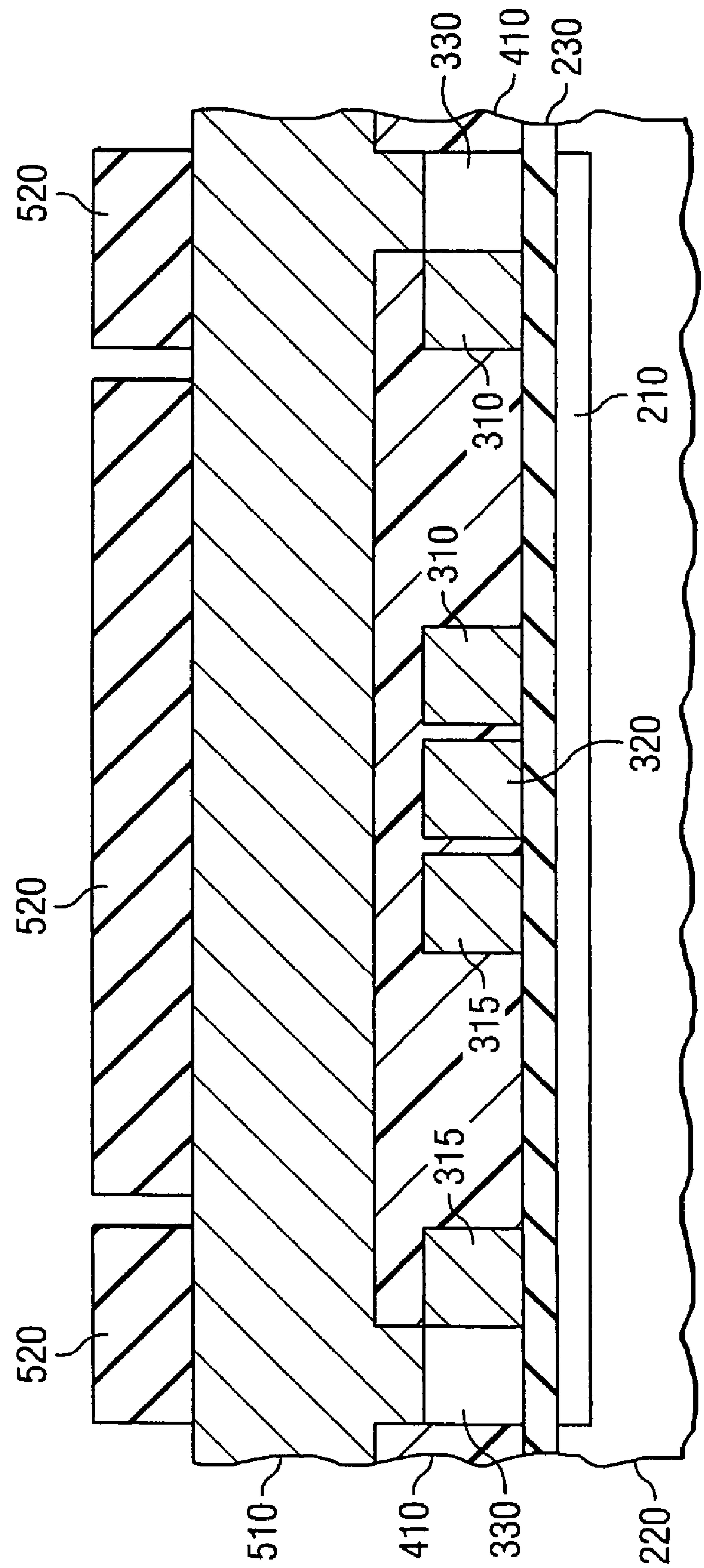


FIG. 5

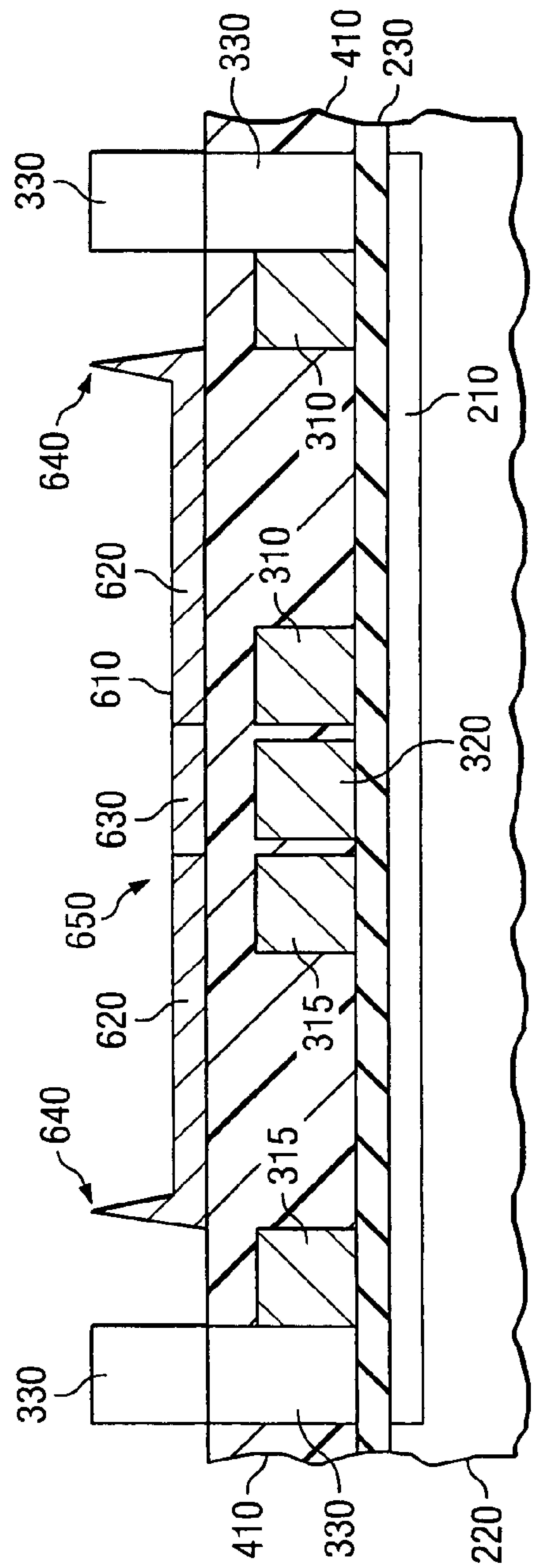

330
410
230
640
620
610
630
650
315
310
320
210
220

FIG. 6

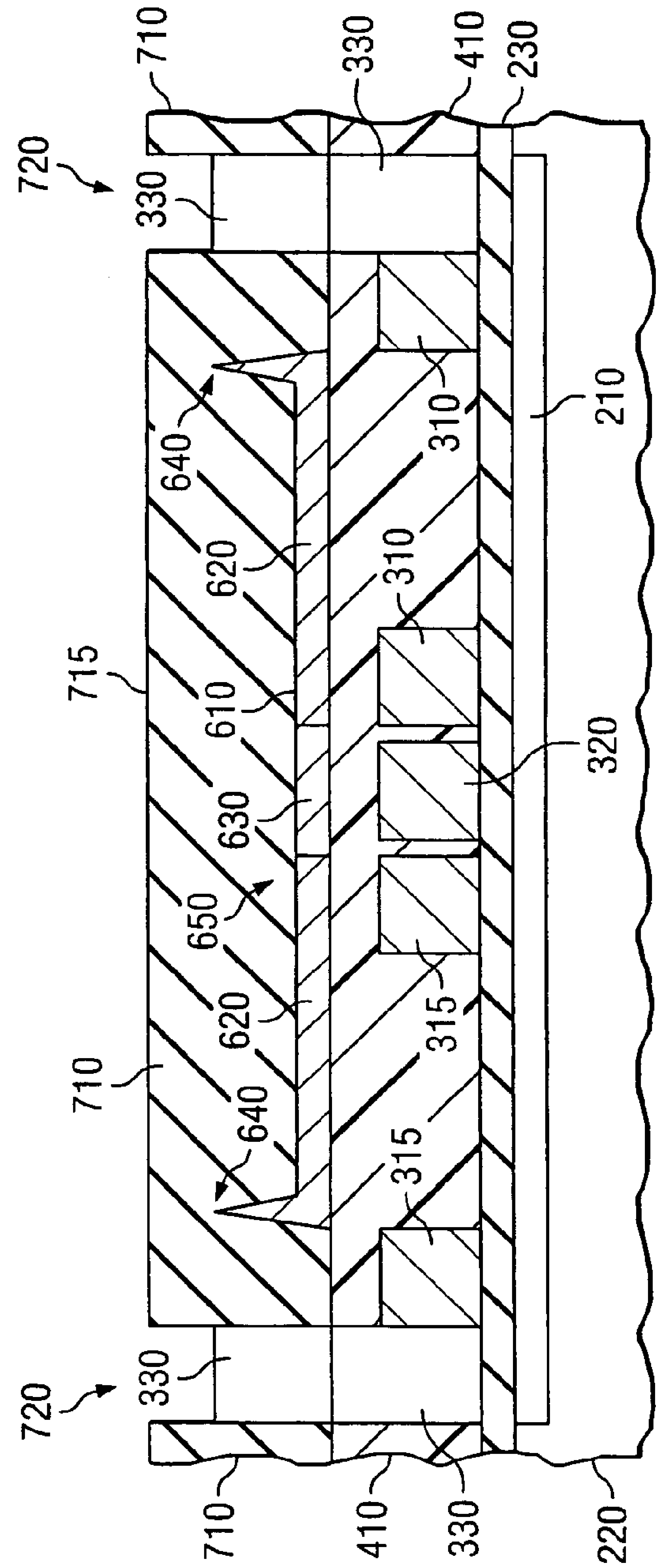

710
720
330
410
230
640
620
610
630
650
715
315
310
320
210
220

FIG. 7

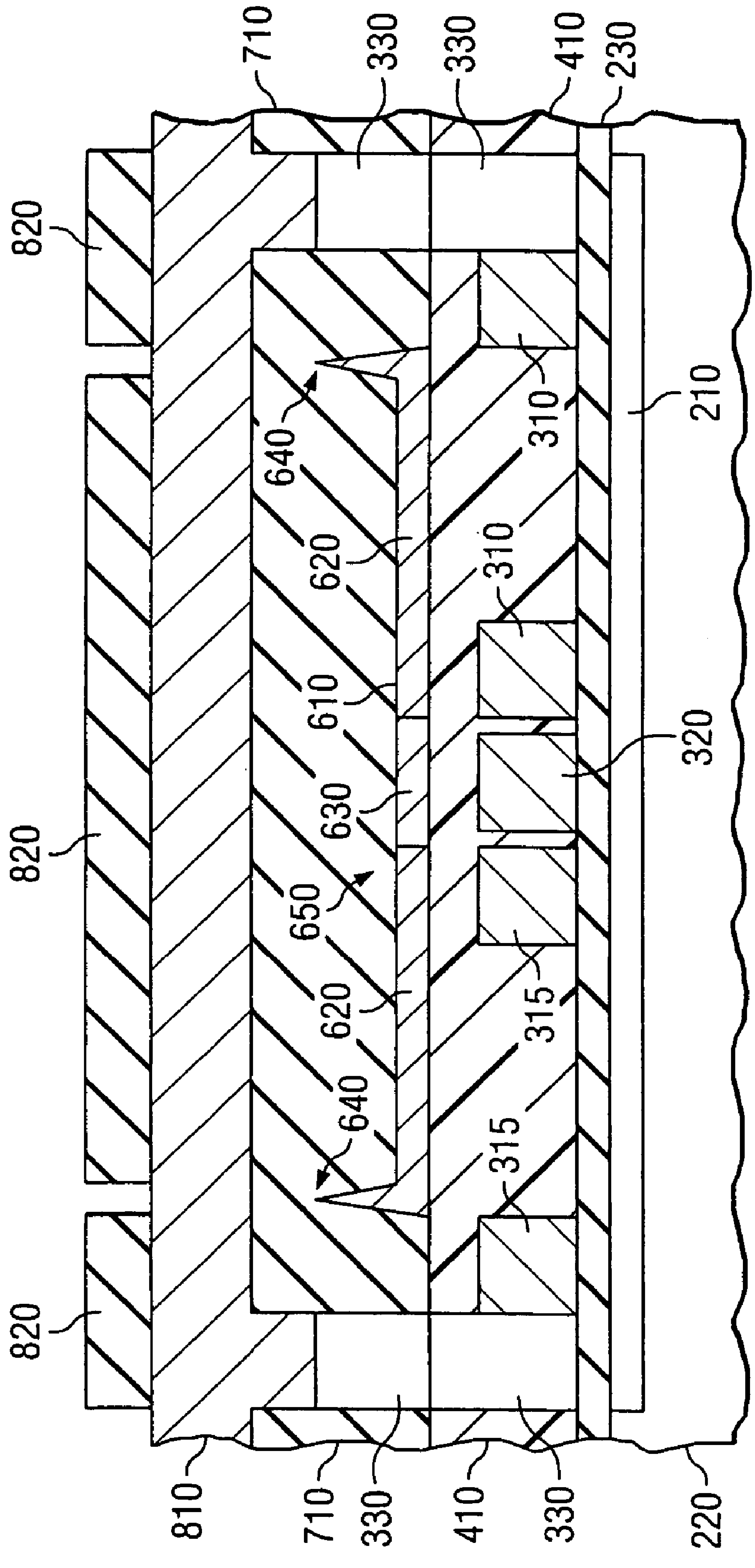

710
330
330
410
230
820
820
820
640
620
610
630
650
620
640
310
310
310
320
315
315
210
810
710
330
410
330
220

FIG. 8

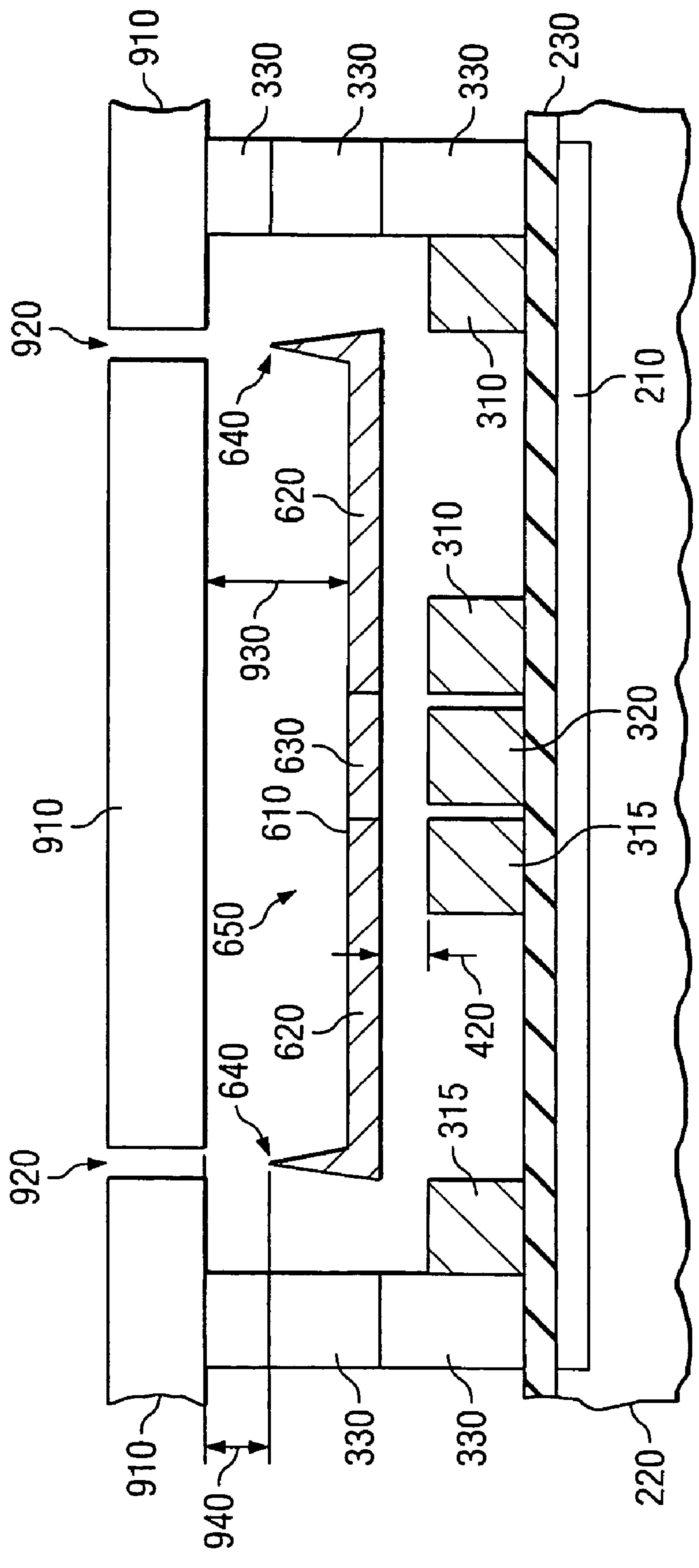

910
330
330
330
230
920
640
620
310
210
930
310
630
610
320
910
650
315
620
420
640
920
315
910
940
330
330
220

FIG. 9

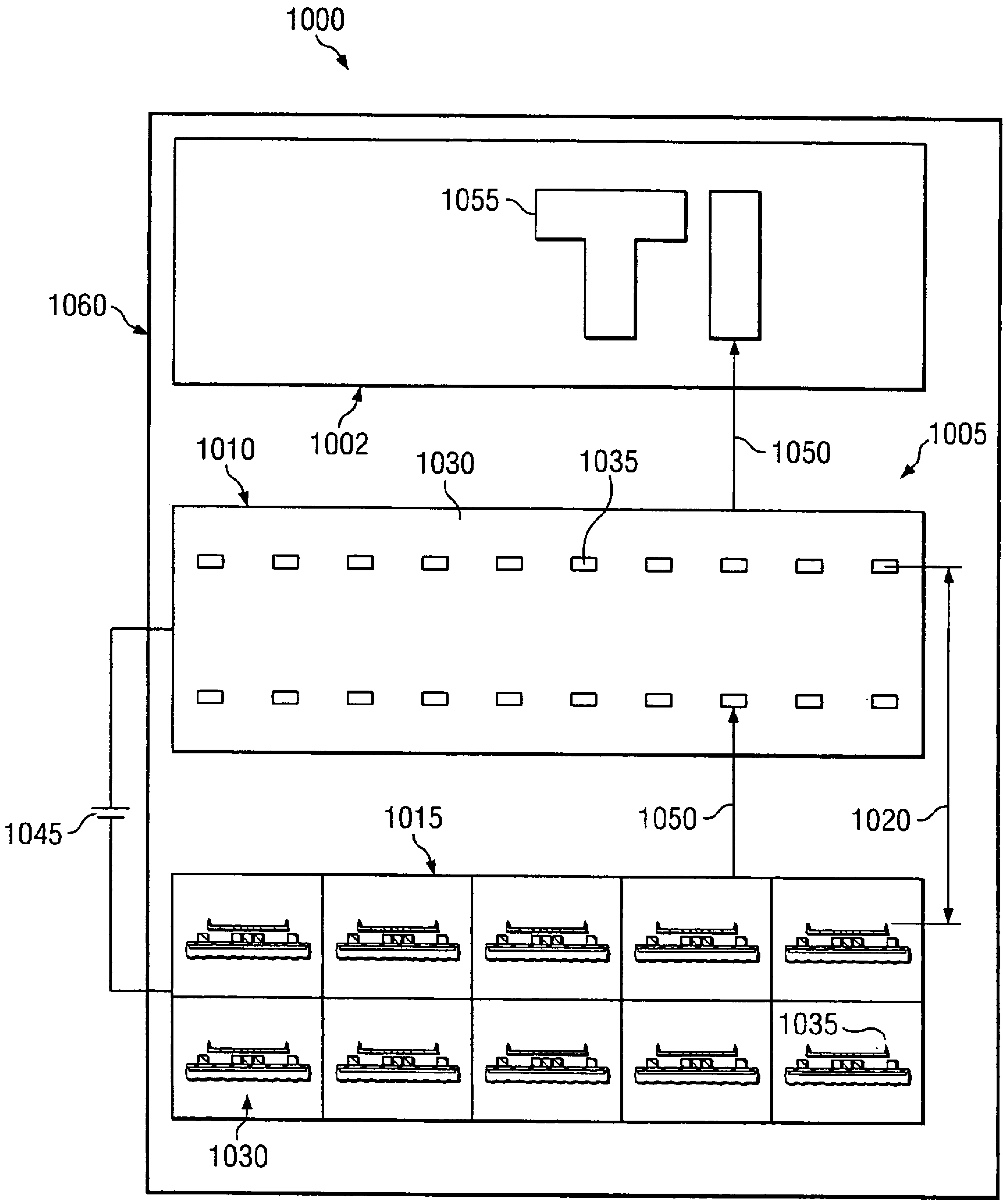

1000
1055
1060
1002
1010
1030
1035
1050
1005
1045
1015
1050
1020
1035
1030

FIG. 10

DISPLAY USING A MOVABLE ELECTRON FIELD EMITTER AND METHOD OF MANUFACTURE THEREOF

TECHNICAL FIELD OF THE INVENTION

The present invention is directed to display technology and in particular, to an electron field emitter display and a method of manufacturing the display.

BACKGROUND OF THE INVENTION

An electron field emitter is a key component in phosphor display technology. Current phosphorous field emission displays require the electron field emitter to be enclosed in a high vacuum and ultra-clean environment. Such an environment is necessary to avoid the rapid deterioration of the types of cathodes currently being used in phosphor displays. Typically these cathodes have a pointed or conical shaped tip.

When a potential is applied between the anode and cathode, cathodes having a pointed or conical tip advantageously concentrate the electrical field strength around the tip. Consequently, relatively small potentials (e.g., less than about 10 Volts) between the cathode and anode of the display are needed to cause the emission of electrons. The ability to use such low potentials has an important benefit because conventional CMOS devices can operate at these low potentials, and therefore can be used to control the emission of electrons.

The use of pointed or conically shaped cathode tips has a major drawback however. The performance of the cathode deteriorates as material deposits on the tip and thereby changes the shape of the tip. Material from the anode can deposit on the cathode tip due to sputtering caused by electrons emitted from the cathode and hitting the anode. Additionally, contaminants remaining or leaking inside the chamber that encloses the cathode can deposit on the cathode tip.

A change in the shape of the cathode tip can change the density of the field around the tip, thereby changing the location from which electrons are emitted. This, in turn, defocuses the phosphor display. Eventually the performance of the cathode deteriorates to the point where the phosphorous display no longer operates within acceptable limits. Decreasing the rate of deterioration by enclosing the electron field emitter in an even cleaner environment or higher vacuum is a major cost in the fabrication of phosphorous displays, and it is becoming prohibitively expensive to improve upon existing vacuum technologies to improve cathode lifetime.

Accordingly, what is needed in the art is an electron field emitter device that can operate in environments that are easy to achieve and has a long lifetime, while not experiencing the above-mentioned problems.

SUMMARY OF THE INVENTION

To address the above-discussed deficiencies of the prior art, the present invention provides, in one aspect, provides a field emission device. The field emission device comprises an anode and cathode. The anode and cathode are separated by a distance, and at least one of the anode or the cathode is configured to move with respect to the other. Movement is in response to a voltage applied to at least one of the anode and the cathode, the distance being adjustable by the movement.

In another aspect, the present invention provides a method of manufacturing a field emission device. The method comprises forming a control circuit in a semiconductor substrate and forming an anode over the semiconductor substrate. The method also comprises forming a cathode over the semiconductor substrate, wherein the cathode is separated by a distance from the anode. The distance is adjustable by moving at least one of the anode and cathode with respect to the other by applying a voltage to at least one of the anode and cathode.

In still another aspect, the present invention provides a display system. The display system comprises the above-described field emission device and a phosphor surface. A current of electrons passing from the cathode to the anode is configured to pass through the anode to cause the phosphor surface to emit light.

The foregoing has outlined preferred and alternative features of the present invention so that those skilled in the art may better understand the detailed description of the invention that follows. Additional features of the invention will be described hereinafter that form the subject of the claims of the invention. Those skilled in the art should appreciate that they can readily use the disclosed concepts and specific embodiments as a basis for designing or modifying other structures for carrying out the same purposes of the present invention. Those skilled in the art should also realize that such equivalent constructions do not depart from the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, reference is made to the following detailed description of example embodiments, taken in conjunction with the accompanying drawings, in which:

FIG. **1** illustrates an exploded perspective view of selected aspects of one embodiment of a field emission device of the present invention;

FIGS. **2-9** illustrate cross-sectional views, corresponding to sections taken along a longitudinal axis of spring element **145** of FIG. **1**, of selected steps in an example method of manufacturing a field emission device following the principles of the present invention; and

FIG. **10** illustrates an exploded schematic view of selected aspects of an example display system of the present invention.

DETAILED DESCRIPTION

The present invention recognizes that the performance of a field electron emitter can be substantially improved by controlling the emission of electrons through dynamic adjustments in the distance between the cathode and anode during the emitter's operation. Electron emission can be controlled in this fashion because the strength of the electric field between the anode and cathode is inversely proportional to the distance between the anode and cathode. As further illustrated in the described embodiments of the invention, controlling electron emissions by having an adjustable distance between the anode and cathode facilitates the incorporation of a number of advantageous cathode designs into field electron emitter devices and displays having such devices.

FIG. **1** illustrates an exploded perspective view of selected aspects of an example field emission device **100** of the present invention. The field emission device **100** comprises an anode **105** and a cathode **110**. The cathode **110** is separated from the anode **105** by a distance **115**. For the purposes of the present invention, the distance **115** refers to the distance separating an aperture **117** of the anode **105** and a portion of the cathode **110** that emits electrons through the aperture **117**. At least one of the anode **105** or the cathode **110** is configured to move with respect to the other, to thereby adjust the distance **115**. The movement of the anode **105**, cathode **110** or both, is in response to a voltage **120** applied to at least one of the anode **105** or cathode **110**.

In some embodiments of the field emission device **100**, the anode **105** is coupled to a first substrate **125**, and the cathode **125** is coupled to a second substrate **130**. The distance **115** is adjusted by at least one of the first and second substrates **125**, **130** being movable with respect to the other by application of the applied voltage **120**. For the embodiment illustrated in FIG. **1**, the first substrate **125** is configured to hold the anode **105** in a fixed location, while the second substrate **130** is configured to move the cathode **110**. Of course in other embodiments of the field emission device **100**, the anode **105** is movable and the cathode **110** is fixed, or both the anode and cathode **105**, **110** are movable.

In some embodiments, the field emission device **100** comprises a plurality of cathodes **110** such as depicted in FIG. **1**, located in proximity to a single anode **105** having a plurality of apertures **117**. In other embodiments, the field emission device **100** comprises a plurality of anodes **105** and cathodes **110** arranged in a two-dimensional array.

It is advantageous for at least one of the first or second substrates **125**, **130** to comprise a microelectromechanical system (MEMS). In certain preferred embodiments, movement is accomplished by coupling the anode **105** or cathode **110** to a first or second substrate **125**, **130** comprising a MEMS. Those of ordinary skill in the art are familiar with various MEMS configurations and how components of the MEMS can be configured to move the anode or cathode in response to an applied voltage. Non-limiting examples of suitable MEMS configurations include MEMS actuators whose motion is electrostatically or piezoelectrically driven. Examples of electrostatically driven MEMS are presented in U.S. Pat. Nos. 5,583,688 and 6,856,446, which are incorporated by reference herein.

For the particular embodiment depicted in FIG. **1**, the first substrate **125** comprises a fixed support body for the anode **105** while the second substrate **130** comprises a MEMS. In some cases, as illustrated in FIG. **1**, in addition to providing mechanical support, the first substrate **125** is also electrically coupled to the anode **105**. Even more preferably, the first substrate **125** electrically couples the anode **105** to a voltage source **135**, which is also electrically coupled to the cathode **110**. Of course in other embodiments, the anode **105** and cathode **110** can each be directly coupled to the voltage source **135**.

The second substrate **130** depicted in FIG. **1** comprises a MEMS having a hinge element **140** and a spring element **145**. For the illustrated embodiment, both the hinge and spring elements **140**, **145** are components of the cathode **110**. The spring element **145** is rotated about the hinge element **140** to change the distance **115** separating the anode **105** and cathode **110**, thereby making the cathode **110** a rotating cathode. The rotation of the spring element **145** is achieved by applying the voltage **120** to one or more electrode pad **150**, **152** electrostatically coupled to the spring element **145**. Preferably the voltage **120** is applied by a control circuit **155** electrically coupled to the electrode pad **150**. It is desirable for the control circuit **155** to comprise a complementary metal oxide semiconductor (CMOS) device. Preferably the electrode pads **150**, **152** can be addressed by the control circuit **155** comprising a CMOS static random access memory (SRAM) cell, such as a five-transistor or six-transistor SRAM cell.

As well known to those skilled in the art, when the voltage **120** is applied, electrostatic fields are developed between the cathode **110** and the electrode pads **150**, **152** creating an electrostatic torque. The electrostatic torque works against the restoring torque of the hinge element **140** to rotate the cathode to a minimal span **160** or maximal span **165** separating the anode **105** and cathode **110**. In some instances, one or more of the electrode pads **152** has an opening **170** to facilitate movement of the cathode **110** through the electrode pad **152** to land on the surface of the control circuit **155**, thereby allowing the cathode **110** to move a greater distance **115** away from the anode **105**.

Some preferred configurations of the second substrate **130** further comprise a bias bus **172** and cathode support post **174**. The bias bus **172** interconnects a plurality of field emission devices **100** preferably arranged in a two-dimensional array, to a common driver that supplies the desired bias waveform for proper digital operation. The cathode support post **174** holds the hinge element **140** above the electrode pad **152** and bias bus **172**, thereby allowing the hinge element **140** to twist in a torsional fashion. One skilled in the art would be familiar with other optional components that could be included in the second substrate **130** to facilitate the movement and support of the cathode **110**.

The cathode **110** in FIG. **1** is depicted for illustrative purposes with first and second tips **180**, **182** having two different shapes: knife-edged and conical, respectively. As part of the present invention, it is recognized that the operating lifetime of the device **100** is increased by configuring the cathode **110** to have a knife-edged tip **180**. As used herein, the term knife-edged tip is defined as cathode having a straight edge **185** that is at least about 5 nanometers long and with a radius of curvature **187** between about 1 nanometer and 20 nanometers.

Under the appropriate conditions, a cathode **110** having a knife-edged tip **180** emits a current of electrons from the entire straight edge **185**. Consequently, even if there is a point failure along the straight edge **185**, electrons are still emitted from other locations along the edge. Therefore, the lifetime of the field electron emitter device **100** is increased as compared to a device having a cathode with a conical-shaped cathode tip **182**. As discussed above, the performance of a cathode having a conical-shaped cathode tip **182** deteriorates when material deposits on or near the tip **182**.

Although an arrangement of differently shaped first and second tips **180**, **182** is within the scope of the present invention, it is more preferable for the cathode **110** to have two tips **180**, **182** of the same shape: either both knife-edged or both conical. Of course, the cathode **110** can be configured to have a single tip or more than two tips, if desired.

As well understood by those skilled in the art, when a suitable potential is applied between the anode **105** and cathode **110** by the voltage source **135**, electrons are emitted from the cathode **110** in accordance with the Fowler Nordheim equation. Unfortunately, a higher potential difference (e.g., at least about 10 Volts) is required to cause electrons to emit from a knife-edged tip **180** than a conical tip **182** for a given distance **115**. Consequently, a control circuit **155** comprising a CMOS device, which typically operates at less than about 10 Volts, cannot be used to directly control the emission of electrons from the knife-edged cathode **180**.

The present invention ameliorates this limitation by providing a field electron emitter device **100** whose anode **105** or cathode **110** is configured to move with respect to the other. As the distance **115** between the anode **105** and cathode **110** is reduced, the strength of the electrical field at the cathode **110** is increased for a given potential difference applied by the voltage source **135** to the anode **105** and cathode **110**. The increased electric field strength promotes electron emission. Conversely, as the distance **115** is increased, the strength of the electric field at the cathode **110** is decreased for the given potential difference, and hence electron emission does not occur.

By decreasing the distance **115** to a minimal span **160**, a device **100** having a cathode **110** with a knife-edge tip **180** can be configured to emit electrons in conjunction with a lower applied potential from the voltage source **135**. Moreover, the emission of electrons can be stopped by increasing the distance **115** to a maximal span **165**. The distance **115** is changed from the minimal span **160** to maximal span **165** by changing the control circuit **155** comprising a CMOS device between its complementary states. For instance, in some preferred embodiments, the complementary states of the CMOS device of the control circuit **155**, corresponding to "on" and "off," are applied voltages **120** of 7.5 and 0 Volts, respectively, or 3.3 and 0 Volts, respectively. In some configurations, the distance **115** is adjusted to the minimal span **160** and to the maximal span **165** when the CMOS device is in the "on" state and "off" state, respectively.

In instances where the cathode **110** has two tips **180**, **182** such as depicted in FIG. **1**, moving the first tip **180** to its minimal span **160** will cause the second tip **182** to move to its maximal span **165**. The movement of the second tip **182** is facilitated by applying a voltage **190** to electrode pads **192**, **194**, analogous to that described above for the first tip **180**.

The emission of electrons from the device **100** is thereby indirectly controlled by the control circuit **155** comprising a CMOS device, through its application of a voltage **120** to move the cathode **110**. Importantly, the applied voltage **120** needed to move the cathode tip **180** between its minimal span **160** and maximal span **165** is less than about 10 Volts. This advantageously allows the control circuit **155** to use conventional CMOS devices, operating at low voltages, to control electron emission.

One skilled in the art would understand how to adjust the potential applied by the voltage source **135** to produce an electrical field sufficient to cause the emission of electrons when the anode **105** and cathode **110** are separated by the minimal span **160**, but to not emit electrons when they are separated by the maximal span **165**. The choice of the potential to apply by the voltage source **135** will depend upon multiple parameters, such as the minimal and maximal distance spans **160**, **165**, the shape of the cathode tip **180**, the applied voltage **120**, and the materials used for the anode **105** and cathode **110**.

As a non-limiting example, consider an embodiment of the device **100**, where the anode **105** and cathode **110** are composed of aluminum or aluminum alloy. The minimal span **160** is from about 300 to 500 nanometers and the maximal span **165** is from about 2 to 10 times longer than the minimal span **160**. The movement of the cathode **110** tip **180** between these distances is accomplished by varying the applied voltage **120** from an "on" state of 7.5 Volts to an "off" state of 0 Volts. Of course, one skilled in the art would understand how to use more complex voltage schemes to drive the movement of the cathode **110**, and how to adjust these and other parameters to accommodate alternative configurations of the device **100**.

In some cases a device **100** configured in this fashion would require the potential from the voltage source **135** to be in the range of about 1 Volt to about 10 Volts. In other cases, however, the required potential can be greater than about 10 volts. The device **100** of the present invention can easily apply potentials of greater than 10 Volts, because the voltage source **135** does not have to contain CMOS devices. Therefore, the voltage source **135** is advantageously not limited to CMOS operating voltages, which typically are maximally about 10 Volts.

FIGS. **2-9** illustrate steps in an example method of manufacturing a field emission device following the principles of the present invention. The method can be used to fabricate any of the embodiments of the field emission device presented in the context of FIG. **1** and discussed above.

FIG. **2** illustrates a partially completed field emission device **200** after forming a control circuit **210** in a semiconductor substrate **220**. Forming the control circuit **210** preferably comprises forming a plurality of CMOS devices, and, more preferably, forming addressable SRAM circuits. Also depicted in FIG. **2** is the partially completed device **200** after covering the control circuit **210** with an insulating layer **230** and forming a metal layer **240** over the insulating layer **230**. The insulating layer **230** preferably comprises an oxide, such as silicon oxide, that has been planarized by chemical-mechanical planarization. The metal layer **240** preferably comprises aluminum or aluminum alloy that has been sputter deposited. Vias are formed in the insulating layer **230** to allow the metal layer **240** to contact the underlying control circuit **210** where necessary.

FIG. **3** shows the partially completed field emission device **200** after patterning the metal layer **240** to form electrode pads **310**, **315**, a bias bus **320** and first substrate **330**. Preferably the metal layer **240** is patterned by plasma-etching using plasma-deposited SiO_2 as the etch mask. In some instances, voids or openings **340** are formed in the electrode pads **310**, **315** to facilitate greater movement of the cathode. In preferred embodiments, patterning to form the first substrate **330** further comprises forming interconnections to a voltage source and cathode (not shown in the cross-sectional views of FIGS. **2-9**).

FIG. **4** presents the partially completed field emission device **200** after forming a first spacer layer **410** over the electrode pads **310**, **315** and bias bus **320** and in the voids **340**. Preferably, the first spacer layer **410** is formed by spin depositing a photoresist and then deep UV hardening the photoresist to a temperature of about 200° C. to prevent flow and bubbling during subsequent processing steps. The first spacer layer **410** is configured to provide a planar surface **415** on which to build the cathode and to provide a gap **420** between the cathode and electrode pads **310**, **315** and bias bus **320**. Conventional patterning and etching techniques are used to form openings **425** in the first spacer layer **410** to allow further construction of the first substrate **330** or the formation of support posts for the cathode (not shown in the cross-sectional views of FIGS. **2-9**).

FIG. **5**. illustrates the partially completed field emission device **200** after forming a second metal layer **510** over the first spacer layer **410**. Preferably, the second metal layer **510** is formed using similar procedures and materials as described above for forming the first metal layer **240**. Also shown in FIG. **5**, an etch mask **520**, such as a plasma-deposited SiO_2 etch mask, is formed over the second metal layer **510** to define a pattern for etching the second metal layer **510**.

FIG. **6** shows the partially completed field emission device **200** after patterning the second metal layer **510** to form a cathode **610** over the semiconductor substrate **220**. Patterning the second metal layer **510** preferably also comprises further forming the first substrate **330**. Similar plasma-etching procedures used to pattern the first metal layer **240** can also be used to pattern the second metal layer **510**. Patterning to form the cathode **610** comprises forming one or more spring elements **620** and hinge elements **630**. In certain instances, it is desirable to perform additional patterning and isotropic etching steps to form one or more tips **640** of the cathode **610**, such as conical or knife-edged tips. It is advantageous if the patterning process to form the cathode **610** also forms electrode pads located in the same lateral plane as the cathode **610** (not visible in the cross-sectional views presented in FIGS. **2-9**) similar to the electrode pads **150**, **194** depicted in FIG. **1**. The patterning is performed to configure the spring element **620** to be electrostatically couplable to the in-plane electrode pads or underlying electrode pads **310**, **315**. The control circuit **210**, electrode pads **310**, **315**, bias bus **320** and cathode **610** are referred to as a second substrate **650**.

FIG. **7** shows the partially completed field emission device **200** after forming a second spacer layer **710** over the second substrate **650**. Again, similar procedures and materials are used to form the second spacer layer **710** as described for forming the first spacer layer **410**. The second spacer layer **710** provides a planar surface **715** on which to build the anode and serves to separate the anode and cathode **610** from each other. Analogous to openings **425** discussed above in connection with the patterning of the first spacer layer **410**, the second spacer layer **710** is patterned to provide openings **720** to allow further construction of the first substrate **330** and to form other anode support structures if needed.

FIG. **8** depicts the partially completed field emission device **200** after forming a third metal layer **810** over the second spacer layer **710**. The third metal layer **810** is formed using procedures and materials similar to those used to form the first and second metal layers **240**, **510**. Also illustrated is a second etch mask **820** formed over the third metal layer **810** to define a pattern for etching.

FIG. **9** illustrates the partially completed field emission device **200** after patterning the third metal layer **810** to form an anode **910** and to further form the first substrate **330**. Patterning the third metal layer **810** also comprises forming one or more apertures **920** in the anode **910**, preferably above the cathode tips **640**. The field emission device **200** is shown after removing the first and second spacer layers **410**, **710**. In some embodiments, the spacer layers **410**, **710** are removed using a conventional plasma-ash process. Removal of the spacer layers **410**, **710** provides gaps **420** below and gaps **930** above the cathode **610** thereby facilitating the movement of the spring element **650**. For the particular configuration depicted in FIG. **9**, the gaps **420**, **930** facilitate the movement of the spring element **650** to adjust the distance **940** separating the anode **910** and cathode **610** at the tips **640** when a voltage is applied to the cathode **610** via the control circuit **210**. Of course, the method can be modified to provide a field emission device in which the anode moves to adjust the distance separating the anode and cathode **910**, **610** in response to an applied voltage.

Still another aspect of the present invention is a display system. FIG. **10** illustrates an exploded schematic view of selected aspects of an example display system **1000** following principles of the present invention. The display system **1000** comprises a phosphor surface **1002** and field emission device **1005**. The phosphor surface **1002** comprises any conventional phosphorescent material used in the construction of cathode-ray tube or similar displays.

The field emission device **1005** can comprise any of the embodiments of field emission devices depicted in FIGS. **1-9** and discussed above. For instance, as illustrated in FIG. **10**, the field emission device **1005** comprises an anode **1010** and a cathode **1015** separated by a distance **1020**. The distance **1020** is adjusted by moving at least one of the anode **1010** or cathode **1015**. At least one of the anode **1010** or cathode **1015** is configured to be movable with respect to the other in response to a voltage applied to at least one of the anode **1010** or cathode **1015**.

For the particular embodiment of the system **1000** illustrated in FIG. **10**, the anode **1010** comprises a metal sheet **1030** having a grid of apertures **1035** therein. The cathode **1015** comprises a plurality of cathode subunits **1030**, configured in a two-dimensional array. Preferably, each cathode subunit **1030** comprises a substrate **1035** having a movable MEMS with a cathode element and a control circuit, such as discussed above in the context of FIGS. **1-9**. For the system shown in FIG. **10**, the cathode **1015** is configured to move to a minimal and maximal span of the distance **1020** when a first and second voltage is applied to the cathode **1015**, respectively. For example, the substrate **1035** of the cathode subunit **1030** can be configured to cause movement of the cathode when a voltage is applied to components of the MEMS via the control circuit.

The system **1000** shown in FIG. **10** also comprises a voltage source **1045** that is electrically coupled to the anode **1010** and cathode **1015**. When a potential is applied by the voltage source **1045**, an electric field is generated between the anode **1010** and cathode **1015**. The appropriate electric field, in cooperation with an adjustment of the distance **1020** to the minimal span as discussed above, causes the emission of electrons **1050** from the cathode **1015**. The current of electrons **1050** passing from the cathode **1015** to the anode **1010** is configured to pass through the anode **1010** to the phosphor surface **1002** thereby causing the phosphor surface **1002** to emit light in the form of a luminescent display **1055**. Of course, the distance **1020** of each cathode element **1030** of the cathode **1015** can be selectively adjusted to cause electron emission from a specific cathode element **1030**, thereby illuminating a specific location on the phosphor surface **1002**.

As further illustrated in FIG. **10**, in some embodiments of the system **1000**, one or both of the phosphor surface **1002** and field emission device **1005** are enclosed in a chamber **1060**. The chamber **1060** is designed to minimize contaminating material from contacting the anode or cathode **1010**, **1015** and thereby deteriorating the function lifetime of the system **1000**. For instance, in some preferred embodiments, the chamber **1060** is hermetically sealed. In other embodiments, the chamber **1060** is also evacuated to further remove contaminating material present in the chamber **1060**. For instance, in some cases the pressure inside the chamber **1060** is reduced below atmospheric pressure. In other embodiments of the system **1000**, however, and the system **1000** is configured to operate at atmospheric pressure (e.g., about 1 atmosphere). In such embodiments, the chamber **1060** is maintained at about 1 atmosphere, or there is no chamber. An acceptable functional lifetime for the system **1000** in such instances is facilitated by configuring the cathode **1015**, and more specifically cathode elements **1030**, to have knife-edged tips.

Those skilled in the art to which the invention relates should appreciate that various changes, substitutions and alterations may be made to the embodiments described herein, without departing from the scope of the invention in its broadest form.

What is claimed is:

1. A field emission device, comprising:

an anode;

a cathode spaced from the anode; the cathode including a hinge portion, and a spring portion having a knife-edge tip rotatable about the hinge portion between a position of minimal spacing and a position of maximal spacing of the tip relative to the anode;

a first voltage source coupled between the anode and cathode for causing electrons to be emitted from the tip when the tip is in the minimal spacing position and to be not emitted from the tip when the tip is in the maximal spacing position; and

a structure including a control circuit and electrode pads; the electrode pads being electrostatically coupled to the cathode for selectively driving the tip between the minimal and maximal spacing positions in response to a voltage applied by the control circuit.

2. The device of claim **1**, wherein the anode includes an opening in alignment with the tip.

3. The device of claim **1**, wherein the electrode pads include an electrode pad having an opening in alignment with the tip.

4. The device of claim **1**, wherein the control circuit is a CMOS circuit.

5. The device of claim **1**, wherein the spring portion is an elongated element centrally joined for rotation about the hinge portion; the knife-edge tip is a first knife-edge tip located at an end of the elongated element; and the spring portion has a second knife-edge tip located at an opposite end of the elongated element.

6. The device of claim **2**, wherein the anode opening is a first opening; the electrode pads include an electrode pad having a second opening in alignment with the tip; and the tip is located between the first and second openings.

7. The device of claim **6**, wherein the control circuit is a CMOS circuit.

8. The device of claim **7**, wherein the spring portion is an elongated element centrally joined for rotation about the hinge portion; the knife-edge tip is a first knife-edge tip located at an end of the elongated element; the first opening is in alignment with the first knife-edge tip; the spring portion has a second knife-edge tip located at an opposite end of the elongated element; the anode includes a third opening in alignment with the second knife-edge tip; and the electrode pad includes a fourth opening in alignment with the second knife-edge tip; the second knife-edge tip being located between the third and fourth openings.

9. The device of claim **8**, wherein the knife-edge of the first knife-edge tip is longer than the knife-edge of the second knife-edge tip.

10. The device of claim **5**, wherein the knife-edge of the first knife-edge tip is longer than the knife-edge of the second knife-edge tip.

11. A display system, comprising:

a field emission device, including:

an anode including an opening;

a cathode spaced from the anode; the cathode including a hinge portion, and a spring portion having a knife-edge tip rotatable about the hinge portion between a position of minimal spacing and a position of maximal spacing of the tip relative to the anode;

a first voltage source coupled between the anode and cathode for causing electrons to be emitted from the tip and to pass through the opening when the tip is in the minimal spacing position and to be not emitted from the tip when the tip is in the maximal spacing position; and

a structure including a control circuit and electrode pads; the electrode pads being electrostatically coupled to the cathode for selectively driving the tip between the minimal and maximal spacing positions in response to a voltage applied by the control circuit; and

a phosphor surface positioned to generate light when electrons are emitted from the tip and pass through the opening.

12. The system of claim **11**, wherein the anode opening is a first opening; the electrode pads include an electrode pad having a second opening in alignment with the tip; and the tip is located between the first and second openings.

13. The system of claim **11**, wherein the electrode pads include an electrode pad having an opening in alignment with the tip.

14. The system of claim **11**, wherein the control circuit is a CMOS circuit.

15. The system of claim **11**, wherein the spring portion is an elongated element centrally joined for rotation about the hinge portion; the knife-edge tip is a first knife-edge tip located at an end of the elongated element; the first opening is in alignment with the first knife-edge tip; the spring portion has a second knife-edge tip located at an opposite end of the elongated element; the anode includes a third opening in alignment with the second knife-edge tip; and the electrode pad includes a fourth opening in alignment with the second knife-edge tip; the second knife-edge tip being located between the third and fourth openings.

16. The system of claim **12**, wherein the control circuit is a CMOS circuit.

17. The system of claim **16**, wherein the spring portion is an elongated element centrally joined for rotation about the hinge portion; the knife-edge tip is a first knife-edge tip located at an end of the elongated element; the first opening is in alignment with the first knife-edge tip; the spring portion has a second knife-edge tip located at an opposite end of the elongated element; the anode includes a third opening in alignment with the second knife-edge tip; and the electrode pad includes a fourth opening in alignment with the second knife-edge tip; the second knife-edge tip being located between the third and fourth openings.

18. The system of claim **17**, wherein the knife-edge of the first knife-edge tip is longer than the knife-edge of the second knife-edge tip.

19. The system of claim **15**, wherein the knife-edge of the first knife-edge tip is longer than the knife-edge of the second knife-edge tip.

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